Climate-Sustaining Agriculture: Carbon Footprints of Organic and Conventional Onions and Wheat

Final Report for GW15-012

Project Type: Graduate Student
Funds awarded in 2015: $24,980.00
Projected End Date: 12/31/2017
Grant Recipient: Washington State University
Region: Western
State: Washington

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Project Information

Summary:

This project examined the primary sources or “hotspots” of greenhouse gases (GHG) on carbon footprint (CF) in organic production systems. More sustainable agriculture must be resilient in the face of climate change and reduce GHG on both per-acre and per-unit product bases. Despite a willingness to make personal and professional changes to reduce their climate impacts, farmers may lack the knowledge and tools to make effective choices. This project provides information and tools to growers to empower changes in actions and behaviors that reduce GHG emissions.

This project analyzed the carbon footprint (CF) of organic crop production on four organic farms of varying sizes in the state of Washington. The primary sources or “hotspots” of GHG were identified and compared, both in terms of inputs and in terms of the various crops. The goals of this project were to identify primary sources of GHG from different organic farms in order to identify commonalities and differences, and to use the results of the analyses carried out to further improve the OFoot Carbon footprint (CF) calculator that is based on farm practices, inputs, infrastructure, and dynamic crop-soil processes. Such a tool can help producers to identify and reduce GHG hotspots, partake in the carbon trading industry, and educate their consumers.

The project found that each operation had different sources of GHG and hotspots in their CF, but certain patterns emerged. Scale of farming operations affected the primary contributors to farm CF. Although total fuel and embodied energy use by large scale field equipment and irrigation systems are larger than those of small equipment and irrigation systems, they can be more efficient on a per area and/or per unit product basis. Equipment sharing on smaller farms can help to spread the embodied energy of equipment across a larger land base. Fuel and energy use was

a large CF contributor on all operations. Use of lower GHG forms of energy such as biodiesel can dramatically lower a farm's total CF, in one case by over 30%.

Introduction

Agricultural systems' contributions to greenhouse gas emissions are from diverse sources such as N_2O emissions from agricultural soils, CH_4 emissions from livestock enteric fermentation, manure management, and emissions from rice paddies, machinery manufacture and maintenance, transport of materials, and the manufacture of crop protection chemicals and fertilizer. Effective mitigation of global climate change from the agricultural sector will require an understanding of the net GHG emissions that are associated with activities, materials and energy used in farming operations and an understanding of the potential cost-effective reductions in emissions (Dick et al., 2008; Moxey, 2008). The calculation of the carbon footprint (CF) of farms and farm products can contribute to this understanding. A CF calculation identifies the quantity, sources and sinks of GHGs associated with on-farm and off-farm activities (depending on the boundary of the system chosen) with the goal of identifying opportunities to reduce GHG emissions and increase GHG sinks in the system. Carbon footprints are expressed in units of CO2-equivalent emissions (CO2-eq), with GHG other than CO2 expressed in terms of their GWP relative to CO2 (Lynas, 2007; Wiedmann and Minx, 2008).

Project Objectives:

The primary goals for this study were:

- To identify opportunities to reduce farm greenhouse gas emissions.
- Further improve the CFC by expanding its allowable inputs.
- Educate farmers and consumers on ways to reduce GHG emissions.

Cooperators

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Research

Materials and methods:

Using a case study approach, we analyzed the CF of four organic vegetable farms in western Washington State. A partial LCA (PLCA), cradle to farm gate, (Monti et al., 2009) was used to determine the emission factors for all important primary and secondary GHG sources and sinks associated with farm management. Data were collected through questionnaires, interviews, and farm visits to view producers' purchasing and operations records. The GHG of the farm, crops and farm operations were then estimated using the data collected, published data on emissions associated farm operations in organic systems (IPCC, 2007; Lai et al., 2008; Hillier et al., 2009). Some of the major source and sinks of carbon taking into consideration in this process are:

- Manufacturing energy and lifespan of equipment, materials, and infrastructure,
- Fuel and electricity use,
- Manufacture of organic fertilizers and other inputs used in the farm up to the farm gate,
- On-farm application of fertilizers, mulches, and other inputs used in the farm,
- Farming operations such method of compost application, weeding, tillage operations, planting, and harvesting,
- Soil CO2 and N2O release and C storage simulated over 30-year period.

Whole farm carbon footprint analyses were conducted in order to assess the total operations and allow for between-crop nutrient cycling in diverse rotations. The footprints and impacts of onion were identified using a subtractive technique. Analyses were conducted both with and without onions in the rotation. The difference between these was allocated to onion production.

Because of the large impact of irrigation systems, and the extreme differences between materials used in small drip systems vs. large iron pipes, irrigation systems were modeled separately. A center pivot system, permanent set system, and both a large scale and small scale drip system were modeled.

For further analysis of potential methods to reduce the CF hotspots of the smallest farm, hypothetical simulations used biodiesel instead of petroleum gasoline and diesel, and used solar powered irrigation in place of the current hydroelectric powered irrigation while other factors were held constant.

Research results and discussion:

Within the field boundary of the farm, not only did the total CF differ among farms but the major contributors differ. On the smallest farm, the materials and operations used in tillage, fertilization, and irrigation were large contributors to the CF of farm operations. On one farm, tillage and related fuel use contributed 32% of the total footprint, and irrigation 18.3% (Adewale et al., 2016). Most of the tillage CF was due to fuel use. In fact fuel use, both for on-farm and off-farm operation, was the primary CF hotspot in the whole farm. The CF of gasoline and diesel can be allocated among the crops based on the management practices for each crop. Production of chard had the highest CF associated with fuel usage in the studied farm, followed by onion and potato.

Irrigation water pumping was a large user of on-farm energy in every case where irrigation is used. This corroborates previous studies in which electricity consumption was identified as a major contributor of indirect GHG emission for the vegetable industry (O'Halloran et al., 2008; Saunders and Barber, 2008). Types of irrigation systems differed among the farms and were analyzed separately. Center pivot irrigation and large scale drip systems tend to carry a lower CF per ha area than solid set or small scale drip systems, for several reasons. However annualized footprints depend greatly on the potential lifespan of the system. A solid set orchard irrigation system had the largest footprint at 1,721 kg CO2-eq per ha. However, such systems may have a useful lifespan of 10-40 years. In comparison a small scale drip system was found to have a footprint of 1,377 kg CO2-eq per ha. This footprint is 20% less, but such a system may only have a lifespan of 5-20 years. A center pivot system was found to have a footprint of 395 kg CO2-eq per ha because the system moves across the land, thus distributing the embodied energy over a larger area. Greenhouses and mobile hoop houses were also meaningful contributors to total farm footprints, but these energy expenditures were applied only to certain crops needing additional growing degree days.

On the largest farm studied, the relative impact of fuel and energy use were much lower. Due to larger field size and farm size, larger equipment was used. On a per-hectare basis and on a per-kg crop basis, large equipment can be more efficient users of fuel and embodied production energy. On all farms, a switch from petroleum-based diesel to biodiesel can greatly reduce the overall farm footprint. In the case of the smallest farm where fuel represented 38% of the overall CF, a switch to biodiesel was estimated to provide a 32% savings in overall farm footprint.

Soil C and N dynamics release greenhouse gases CO2 and N2O and also store C as soil organic matter and crop residue. Because fuel and energy use dominated the CF on small farms, only on the large farms was the soil dynamic the largest or close to the largest contributor to CF. All of the farms were organic and used organic fertilization such as compost, manure, and cover crops. Despite observing stable or increasing overall soil C, release of N2O from N cycling led to positive CF from soils overall.

Participation Summary

Educational & Outreach Activities

PARTICIPATION SUMMARY:

Education/outreach description:

1. Adewale C., L. Carpenter-Boggs, U.E. Zaher, S.S. Higgins, D.M. Granatstein. 2016. Identifying hotspots in the carbon footprint of a small scale organic vegetable farm. Agricultural Systems 149:112-121.

2. “Farm size effect in modelling carbon footprint of organic farming systems - case study of two farms in Washington State” at the The International Society for Ecological Modelling Global Conference 2016, Modelling of ecosystem services for improved decision making session, Townson University, Baltimore, MD, May 8-12, 2016.https://elsevier.conference-services.net/programme.asp?conferenceID=3935&action=prog_list&session=37759

3. “Identifying Hotspots in the Carbon Footprint of a Small Scale Organic Vegetable Farm” at ASA, CSSA and SSSA International Annual Meetings (2015), Synergy in Science: Partnering for Solutions, Minneapolis, MN, Nov 15-18,

2015. https://scisoc.confex.com/crops/2015am/webprogram/Paper95093.html

4. "Environmental Footprint of Organic Farming" Tilth Producers of Washington 2015 Annual Conference, Building Tilth: Fields, Farmers, and Community, Spokane, WA, November 13-15, 2015. http://tilthproducers.org/audio/2015-c3-the-environmental-footprint-of-organic-farming/

Project Outcomes

Project outcomes:

1. Public release of organic farming carbon footprint calculator, ofoot.wsu.edu.
2. Engaging hundreds of farmers in Pacific Northwest region through Tilth conference and Agriculture in a Changing Climate Workshop. Farmers were trained on how to use the Ofoot tool at Tilth Producers of Washington Conference.
3. Engaging scientists and educators through participation in ASA, CSSA and SSSA International Annual Meetings and The International Society for Ecological Modelling Global Conference.
4. Development of deductive rotational method for calculation of soil emissions attributable to a crop in farm rotation.

Economic Analysis

n/a

Farmer Adoption

Farmers engaged in the study are switching or considering switches to alternative energy sources. Because energy and petroleum based fuels were large contributors to total carbon footprints, switching to biodiesel and solar energy are approaches that can reduce footprints but do not overly complicate daily operations.

Recommendations:

Areas needing additional study

A significant but expected finding of this study is that each farm will have a different carbon footprint, and different sources of greenhouse gases and embodied energy. We look forward to the use of the OFoot online calculator by many growers and researchers in order that the diversity of sources and solutions can be explored.